Provision of noxious facilities using a market-like mechanism: A simple implementation in the lab[*]

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Abstract

We study the provision of a public project that globally behaves as a public good but locally behaves as a private bad. This scenario imposes two problems: *(i)* find a compensation that makes the project acceptable for the pre-determined host, and *(ii)* secure the budget to pay for the project and the required compensation. We use a market-like mechanism with two useful properties for this scenario: players can either contribute or request subsidies to fund the public project, and players have veto power over the desired project quantity. In our game, two players benefit from a waste incinerator, whereas the third group member, the host, is harmed if the facility is too large. We analyze the efficiency and the redistributive potential of this mechanism, with and without communication among group members. We find that the probability of positive provision did not differ with and without communication. However, average provided quantities with respect to the efficient quantity increased from 54% to 81% with communication. We also find that contributions fell below the Lindahl taxes, allowing the players who benefit from a larger facility to accrue most of the efficiency gains. The latter result is consistent with the infrequent evidence of veto threats as a bargaining strategy.

Keywords: lab experiment; NIMBY; LULU; public goods;

JEL Classification Codes: C92, H4, Q58

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1 Introduction

Public projects that are asymmetrically valued among their global and local users might lead to "NIMBY" (Not In My Back-Yard) problems (Schively, 2007). Waste management facilities, nuclear reactors, and prisons are examples of these projects, defined as noxious goods, because they provide a public benefit at the global level, but create a private cost to the project host.

The provision of a noxious project poses two problems. First, a *compensation problem*: finding a transfer that would be acceptable for the host to allow the project to be implemented. Second, a *funding problem*: since multiple parties will benefit from the project implementation, contribution rules must aim at securing a budget that is sufficient to cover the implementation and compensation costs of the project. We borrow the mechanism proposed by Van Essen and Walker (2017) for public goods provision to tackle these problems.

In the Van Essen and Walker mechanism (vEW mechanism hereafter), each player i submits her maximum intended contribution per project unit c_i, and the maximum quantity of the project q_i that she is willing to accept. The mechanism then selects the lowest q_i from the profile of maximum desired quantities; after that, the mechanism validates that the sum of contributions per unit is at least as large as the cost per unit of the project. The simplicity of this mechanism is summarized by the following message describing any individual strategy:

"I will agree to the provision of any amount of the project that is not greater than $\boldsymbol{q_i}$ units, as long as my contribution does not exceed $\boldsymbol{c_i}$ for each unit."

The vEW mechanism has two useful properties in the context of providing noxious projects. First, the proposed contribution per project unit c_i can be negative (i.e., a subsidy). This property allows the host to request a compensation as part of the mechanism. Second, a proposed quantity $q_i = 0$ will prevent the implementation of the project. This property grants that every player, but in particular the host, can veto the project.

Although the mechanism is, in theory, simple to grasp, its implementation in the laboratory offers an initial testing ground for its performance. In particular, the efficient provision of noxious goods is tightly connected to how veto power is employed. Experimental tests of asymmetric veto power in redistribution games (i.e., without opportunities to increase the surplus) have shown that veto power is actively employed (Kagel et al., 2010). In our game, the excessive use of veto power blocks efficient allocations; but if veto power is underused, or the threats of using it are non-credible, the redistribution of the surplus is limited.

In our experimental setting, participants are randomly assigned to groups of three players. Two group members derive a net benefit from the public project; and the third one is the host of the noxious facility, and is harmed if the project quantity is not too small. We framed this problem as the collective decision between the representatives of three Cities, A, B and C (one per player), regarding the construction of a garbage incinerator. City C is predefined as the host of this facility. In each round, participants must submit the maximum quantity of the project that they are willing to support, and the maximum contribution (or minimum requested compensation) per unit of the public project. Given the novelty of this mechanism, we are interested in understanding whether its users are able to attain efficient implementations; and, conditional of project provision, we see if players use their veto power to exploit the redistributive nature of the mechanism.

We find that 66% of the group interactions led to a positive provision level of the public project. However, the efficient quantity, based on the Lindahl Equilibrium prediction, was reached only in 5% of the interactions. We added communication as a between-subjects treatment variation by letting players chat with their teammates during the entire round. We find that, although the probability of positive provision only increased to 68%, the efficient quantity was reached in 37% of the interactions. Moreover, the provided quantity relative to the efficient level increased from 53% to 79% in the treatment with communication.

This study contributes to three strands of the literature. First, we use mechanism design in setting the quantity (or size) of a noxious facility. So far, mechanism design applied to the provision of noxious goods have focused on answering *where* to locate a project but not on *how large* the project should be (Jackson and Moulin, 1992; Kleindorfer and Sertel, 1994; Kunreuther and Kleindorfer, 1986; Kunreuther et al., 1987; O'Sullivan, 1993).[1] These studies have mainly used auctions. More recent studies explore the informational requirements of these auctions (Lescop, 2007), and how to induce interim and ex post voluntary participation (Minehart and Neeman, 2002).

The experimental evidence on the use of auctions for locating noxious facilities is scarce. Kunreuther et al. (1987) proposed an auction in which the party with the lowest bid, representing its willingness to accept (WTA) is selected as host, and each one of the non-selected parties paid an equal share $1/(N-1)$ of the WTA as compensation. The accompanying experiment reveals that learning plays an important role: some rounds are required to guarantee that the auction winner is the player with the lowest provision costs. Quah and Yong (2008) evaluate four different mechanisms in terms of efficiency and revenue, and finds that, from an efficiency perspective, the best performer is the second-price auction and the worst performer is the all-pay second-price auction.

We contribute to this literature by implementing an alternative mechanism that focuses on the compensation problem as a function of how large is the noxious facility. Moreover, we observe that, despite the bi-dimensional nature of requests (i.e. a maximum contribution per unit and a

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[1] Even the acronyms employed to refer to this problem, NIMBY and LULU (Locally Unwanted Land Use), evoke the spatial nature of this situation (Popper, 1983; Schively, 2007).

maximum allowed quantity), positive provisions occur in two-thirds of the interactions. We interpret this result as evidence that the mechanism was sufficiently tractable, and this is confirmed by analysis of the chat logs.

Second, our study contributes to the institutional design of participatory processes by endowing with political power the hosting communities affected by noxious projects. A notorious example are the 'Free, Prior and Informed Consultations," or FPIC processes, which have consolidated as representation mechanisms in Latin American countries demanding the approval of vulnerable groups (e.g. indigenous populations) before large-scale resource extraction projects can take place (Fontana and Grugel, 2016). FPIC processes were conceived as protective and compensatory mechanisms. However, they often stagnate in legal procedures, failing to accomplish their ultimate goal of reducing power asymmetries (Rodríguez-Garavito, 2011). The tension between achieving optimal compensations and allocating the decision power is also innate to the vEW mechanism, and learning about how these forces balance in a controlled setting is useful to conceive transparent mechanisms inspired by mechanism design. We find that veto threats are rare and, as a result, most of the efficiency gains from the mechanism are kept by the players who benefit from a larger noxious facility.

Third, our study adds evidence to the experimental literature exploring mechanisms that, theoretically, can achieve Lindahl efficiency (Smith, 1979, 1980; Banks et al., 1988; Chen, 2008). Van Essen et al. (2012) compare the dynamic properties of three mechanisms, proposed by Walker et al. (1981), Kim (1993), and Chen (2002). Whereas the Kim and Chen mechanisms produce 70-95% of the consumer surplus achieved in equilibrium, behaving better than the Walker mechanism, the Kim mechanism produced fewer violations of individual rationality and budget imbalances were less costly. More recently, Van Essen and Walker (2019) show that the vEW mechanism performs at least as well as the Chen mechanism.

We contribute by testing the vEW mechanism, which can achieve Lindahl efficiency, in a context of a larger asymmetry in valuation between the project host and those who benefit from a larger project size. We find that the consumer surplus with respect to the Lindahl outcome is 35% for the for the former, and 94% for the latter. We also find that non-binding communication, an institution relatively inexpensive to provide that is efficiency-enhancing in public goods games (Isaac and Walker, 1988) and promotes redistribution in bilateral bargaining (Roth, 1995; Andreoni and Rao, 2011), increases the surplus with respect to the Lindahl outcome to 56% for the player hosting the facility, and 105% for the non-hosting players.

The paper proceeds as follows. Section 2 describes the game setting to study the provision of the noxious facility, and explains the vEW mechanism and its properties. Section 3 explains the experimental set up, as well as the experimental variations and hypotheses. Section 4 presents the results. Section 5 concludes the paper.

2 Theoretical background

2.1 The van Essen and Walker mechanism

A set of η players must decide how many units q of a public project they will provide, and how much they will pay for this project. To do so, each player i, for $i \in \{1, \ldots, \eta\}$, makes a proposal $\zeta_i = (q_i, c_i)$, where q_i is the maximum number of project units she is willing to accept, c_i is the maximum contribution per unit of the public project that she is willing to provide, and ϕ is the cost of providing one unit of the project. Given a budget e, the proposal ζ_i must be such that $q_i \times c_i \leq e$. The input of the vEW mechanism is the profile of proposals $\zeta = ((q_1, c_1), \ldots, (q_\eta, c_\eta))$, yielding:

$$q = \begin{cases} min\{q_1, \ldots, q_\eta\} & \text{if } \sum_{i=1}^{\eta} c_i \geq \phi \\ 0, & \text{otherwise,} \end{cases} \tag{1}$$

and

$$p_i = \phi/n + c_i - \bar{c} \quad \text{with} \quad \bar{c} = 1/n \sum_{j=1}^{\eta} c_j \tag{2}$$

Since p_i is the contribution per unit made by player i, the total contribution when q units of the public project are provided will be $T_i = p_i \times q$.

Van Essen and Walker (2017) remark that every outcome of this mechanism is acceptable, in and out of equilibrium. Acceptability dwells in two conditions. For every player: *(i)* contributions per project unit should not exceed the intended contribution; and *(ii)* the provided quantity should not exceed the desired quantity of the project. The latter condition relates to the veto power granted to every participant, since the mechanism selects the minimum of all proposed quantities. In our game, this feature is particularly important for the project host, who can block a project by setting $q_i = 0$.

In addition to acceptability, other important properties of the mechanism that are relevant to our study are: *(iii)* the mechanism is budget balanced, *(iv)* a Nash equilibrium of this mechanism is individually rational, and *(v)* the Lindahl outcome is an equilibrium outcome. For a detailed discussion of these properties see Van Essen and Walker (2017) and Van Essen and Walker (2019).

2.2 Game setting to study the provision of a noxious good

Three players face the problem of provision of q units of a public project. Players 1 and 2, which are symmetric, are of Type B, as they benefit from the public project. Player 3 is of Type H, as she will host the noxious facility associated to the project. The valuation of providing q units of this project for a Type i player is given by $v_i(q) = a_i q - q^2$ for $i \in \{B, H\}$. We set the parameters as $a_B = 14$, and $a_H = 2$, to accentuate the differential character of the public project for Type B players, who benefit from its provision; and for the Type H player, who results harmed if any quantity $q \geq 3$ is provided. All three players receive an endowment of $e = 30$ and face the same costs function $\Phi(q) = \phi q$, with a unit cost $\phi = 6$.

The total surplus is given by

$$S(q) = 2(v_B) + v_H - \Phi(q) = 24q - 3q^2 \tag{3}$$

The maximization of Eq. 3 yields the Pareto optimal provision of the public project, $q^* = 4$. The associated Lindahl tax per unit of public project for Type i, τ_i, is given by setting the marginal rate of substitution, $a_i - 2q$, equal to the marginal cost of the public project, ϕ. We thus obtain $\tau_B = 6$ and $\tau_H = -6$. Therefore, Type B players pay a tax $T_B = 6 \times 4 = 24$ each, for the provision of $q^* = 4$ units of the public project, and the Type N player receives $(-)T_H = (-)6 \times 4 = (-)24$ as compensation, given q^*.

If players would have taken decentralized provision decisions, the predicted quantity would have halved with respect to the optimal level (i.e., $q = q^*/2 = 2$). Note that, for the Type H player, the costs of project provision exceeded its benefits for any value of q and therefore she will not contribute. With the response of Type H Player in mind, the two symmetric Type B players maximize $14(2q_B) - (2q_B)^2 - 6(2q_B)$, yielding $q_B^* = 2$.

The mechanism solution

Following Theorems 2.2 and 2.3 in Van Essen and Walker (2017), the unique Pareto Efficient Nash equilibrium outcome and the unique strong Nash equilibrium outcome is the Lindahl outcome. The two Type B players will submit a contribution of $c_B = 6$ per unit of public project, and will propose a quantity of (at least) $q_B = 4$ project units. The Type H player will submit a negative contribution (i.e., will request a compensation) of $c_H = -6$ per unit of public project, and will propose a quantity of $q_H = 4$ project units.

The profile of proposals $\zeta = ((q_1, c_1), (q_2, c_2), (q_3, c_3))$ will be $\zeta = ((q_1 \geq 4, 6), (q_2 \geq 4, 6), (4, -6))$. Regardless of the values of q_1 and q_2, the minimum quantity will be $q_3 = 4$, hence $q^* = 4$. The sum of contributions per project unit will exactly cover ϕ. Given that $\phi/n = \bar{c}$, using Eq. 2 we

Table 1: Experimental parameters and equilibrium outcomes of the vEW mechanism

Player	Type	a_i	q_i^*	q_i	c_i	p_i	q^*	T_i^*	$\pi_i(q^*, T_i^*)$	$\pi_i(0,0)$
1	B	14	2	≥ 4	6	6	4	24	46	30
2	B	14	2	≥ 4	6	6	4	24	46	30
3	H	2	0	4	-6	-6	4	-24	46	30

For player i, q_i^* corresponds to the decentralized solution, q_i to the requested quantity in the vEW mechanism, c_i to the maximum intended contribution per project unit, p_i to the actual contribution per project unit, q^* and T_i^* to the Lindahl equilibrium quantity and total tax (respectively), and π_i to the payoff.

know that each player will pay her intended contribution per unit, or $p_i = c_i$. The contribution per unit is identical to the Lindahl tax, $p_B = \tau_B = 6$ and $p_H = \tau_H = -6$. This yields a total tax (or compensation) equal to $T_i = p_i q$, and the payoff will be given by $\pi_i = e - T_i + v_i(q)$.

Our parameterization grants that, if the Lindahl allocation is implemented, payoffs are identical for the Type B and Type H players ($\pi_B(q^*, T_B^*) = \pi_H(q^*, T_H^*) = 46$). This is very useful to avoid an efficiency-equality trade-off that might confound motives for selected actions. Table 1 displays the parameter values, optimal strategies and outcomes in equilibrium when using this mechanism. Note that payoffs are also equal when the project is not provided ($\pi_B(0,0) = \pi_H(0,0) = 30$), and these payoffs are identical to the endowment.

3 The experiment

3.1 Experimental set up

We designed and conducted an experiment that emulates the game setting described in Section 2.2. To ease the interpretation and purpose of the mechanism, the instructions were framed as a problem of building a waste incinerator (see Appendices A.1 and A.2 for instructions in English and Spanish, respectively). Participants were told that each one of them represented a city. The two Type B players were assigned to the labels of "City A" and "City B." The Type H player represented "City C." We randomly assigned participants to a label, and then to groups of three players. The labels and groups remained fixed for the ten rounds comprised in the experiment.

In our framing, the National Government suggested to Cities A, B, and C the construction of a waste incinerator that will benefit the three cities. Due to a external restriction the incinerator could only be built in City C. Cities A and B have millions of inhabitants, and would benefit from a large incinerator. By contrast, City C is much smaller, and therefore a small incinerator is preferred. Besides, the environmental costs, increasing in the size of the incinerator, are burdened by City C.

Table 2: Benefits of the public project shown to participants in the experiment

Benefits	Burning Towers in the Incinerator (Q)										
	0	1	2	3	4	5	6	7	8	9	10
City A	0	13	24	33	40	45	48	49	48	45	40
City B	0	13	24	33	40	45	48	49	48	45	40
City C	0	1	0	-3	-8	-15	-24	-35	-48	-63	-80

The "size" of the garbage incinerator is given by the number of burning towers it has. Participants can propose any number of burning towers between 0 and 10 (i.e., $q_i \in \{0, \ldots, 10\}$). Table 2, describing the benefits (or harms) of the incinerator for each City, as a function of q, was available to all three group members from the beginning of the experiment. The values reported in this table were computed based on the parameterization described in Section 2.2.

Given the complexity of the game, the first three rounds were practice rounds. One of the remaining seven rounds was randomly selected for payment. All the participants within a group were paid based on the same selected round. The currency in the experiment were tokens. Players were told that the amounts of tokens earned in the round selected for payment will be multiplied by COP 1,000 to compute their earnings.[2] Note also that Type H participants may end up with negative earnings if they submit $q_i > q^*$ and $c_i > 0$. In the instructions we explained that negative payoffs were rare but possible, and they could be easily avoided by carefully reading how the mechanism works.

3.2 Timing of the experiment

i) **Introduction.** Participants read the general instructions of the experiment and signed the informed consent.

ii) **Validation.** Participants responded to a validation test to check their understanding of the mechanism (see Appendix A.3). The test consisted on three scenarios with a total of ten questions about mechanism outcomes and participants' contributions and payoffs. In case of a mistake, the program provided the correct response with the corresponding explanation.

iii) **Submission.** [Rounds 1-10] Participants submit their proposal $\zeta_i = (q_i, c_i)$. Each participant has 120 seconds to submit her proposal. The default proposal, applied when the player did not submit any ζ_i, was $\zeta_i^0 = (0, 0)$.

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[2] By the time of the experiment, USD 1 was equivalent to COP 3,360.

iv) **Resolution.** [Rounds 1-10] Participants received feedback on the outcome of the mechanism (i.e., provided quantity, sum of contributions, total tax) and their own payoff.

v) **Payment.** [After Round 10] Participants received a summary of their payoffs in each round, and they were informed of their selected round for payment and their final earnings.

3.3 Experimental design and hypotheses

We are interested in the efficiency (via quantities) and redistributive potential (via taxes) of the mechanism in the context of providing a continuous noxious facility. This provision is subject to two types of failures: underpovision (i.e, $q < q^*$); and insufficient contributions (i.e., $\sum_{i=1}^{\eta} c_i < \phi$).

We define two treatments:

- *Baseline*: participants interact under the conditions described in Sections 3.1 and 3.2.
- (with) *Chat*: in the submission stage (see Section 3.2), participants have a chat box located above the submission box. Participants are instructed to talk about their proposals *"in terms of quantities (Q) and contributions ($P > 0$) or compensations ($P < 0$)"*.

We explore whether communication serves an efficiency-enhancing role within this mechanism throughout two types of messages: first, Type H players can request larger compensations per unit in exchange for increasing the allowed project quantity; second, Type B players can ensure that their contributions are sufficient. Our first two hypotheses, associated to the submitted contributions and allowed quantities, read as follows:

(H1) The absolute value of proposed contributions ($|c_i|$) is larger in the *Chat* treatment than in the *Baseline*.

(H2) The proposed quantities from Type H players (q_i^H) are larger in the *Chat* treatment compared to the *Baseline*.

In **H1** we use the absolute value to reflect the idea that Type B players should contribute more, in response to the larger compensations requested by the Type H player (i.e., more negative values of c_i). These larger compensations should be accompanied, in theory, by an increase in the project quantity that a Type H player will allow, as stated in **H2**. In **H2** we do not hypothesize about the quantities proposed by Type B players because the mechanism selects the minimum q_i, which is expected to be provided by the Type H group member.

The other two hypotheses are related to the extensive and the intensive margin in the project provision:

(H3) The probability of a positive provision (i.e., $q > 0$) is higher in the *Chat* treatment compared to the *Baseline*.

(H4) The provided quantity of public project, q, is higher in the *Chat* treatment compared to the *Baseline*.

In **H3** we hypothesize that allowing group members to communicate decreases the likelihood of exerting veto power (i.e., $q_i = 0$), and it also decreases the likelihood of insufficient contributions given a minimum desired project quantity q. Besides, in **H4** we hypothesize that communication also gives players the opportunity to reach agreements with larger contributions compensating larger project quantities.

As a final comment, note that **(H4)** is not a mechanic result of **(H2)**. Type H players might agree to increase the proposed quantity, but their requested compensations could be larger than the contributions of Type B players.

3.4 Sample and implementation

The experiment was conducted in the Rosario Experimental and Behavioral Economics Lab - REBEL, in Bogotá (Colombia), in September 2019. The experiment was programmed and implemented using oTree (Chen et al., 2016). We conducted six sessions with 132 participants in total. In each treatment we had two sessions with 24 participants, and one session with 18 participants. The average payment was COP 38,340 (std. dev. 9,147). This payment was equivalent to USD 11.4 at the time of the experiment.

For this experiment we only recruited undergraduate students from the Economics Department at Universidad del Rosario. We employed this selected sample for two reasons. First, numeracy skills are important in this experiment to prevent underprovision, insufficiency of contributions and negative payoffs based on the misunderstanding of the rules. Second, the framing of the experiment might be particularly appealing for undergraduate students in Economics, increasing the attention paid to the instructions. Given the novelty of the experimental paradigm we wanted to reduce sources for failures of the mechanism associated to misunderstanding of the rules or boredom.

4 Results

We report first the submitted proposals $\zeta_i = (q_i, c_i)$ with and without communication. This is followed by an analysis of the outcomes of the mechanism in terms of efficiency and redistribution.

Table 3: Descriptive Statistics on Submitted Prices and Quantities

	Proposed Contributions		**Proposed Quantities**	
	Type B	Type H	Type B	Type H
Mean	4.75	-3.42	3.69	2.92
Std. Dev.	3.25	4.42	1.59	1.39
Median	5	-4	4	3
Treatment Comparison				
Baseline (mean)	4.693	-2.732	3.936	2.632
Chat (mean)	4.809	-4.109	3.452	3.213
p-value (t-test)	0.5974	0.001	<0.001	<0.001
Observations	880	440	880	440

Then, we explore whether inefficient provisions were mostly due to insufficient contributions or quantity restrictions (including vetoed proposals). In the last part of the section we analyze chat logs to gain insight into how players interacted with the mechanism.

4.1 Proposed contributions and quantities

Table 3 reports the proposed contributions and quantities by player type. Type B players propose to contribute, on average, 4.75 ±3.25 tokens per unit of public project.[3] The bottom part of the table reveals that the average proposed contribution by Type B players does not differ with and without communication, even if we use an overpowered $t-$test assuming statistical independence of observations. Type H players request, on average, 3.42 tokens ±4.42 per unit of public project. The differences between treatments reveal that allowing communication increased the average tokens requested by Type H players by 1.37 tokens. Although this difference appears to be statistically significant, we withhold any conclusions until the regression analysis reported at the end of this section.

Figure 1 complements this analysis by displaying distributions of proposed contributions between treatments (in each panel) and between player types (one per panel). The left panel confirms that the distribution of proposed contributions from Type B players is very similar with and without communication. However, note that the likelihood of submitting the contributions $c_i^B = 0$ and $c_i^B = 7$ increases at least twice with communication. These two contribution levels appear to reflect unsuccessful and successful agreements emerging from communication, respectively. The right panel reveals that Type H players request larger compensations with communication. For instance, the modal (negative) contribution c_i^H shifted from -3 in the baseline to -5 in the *Chat* treat-

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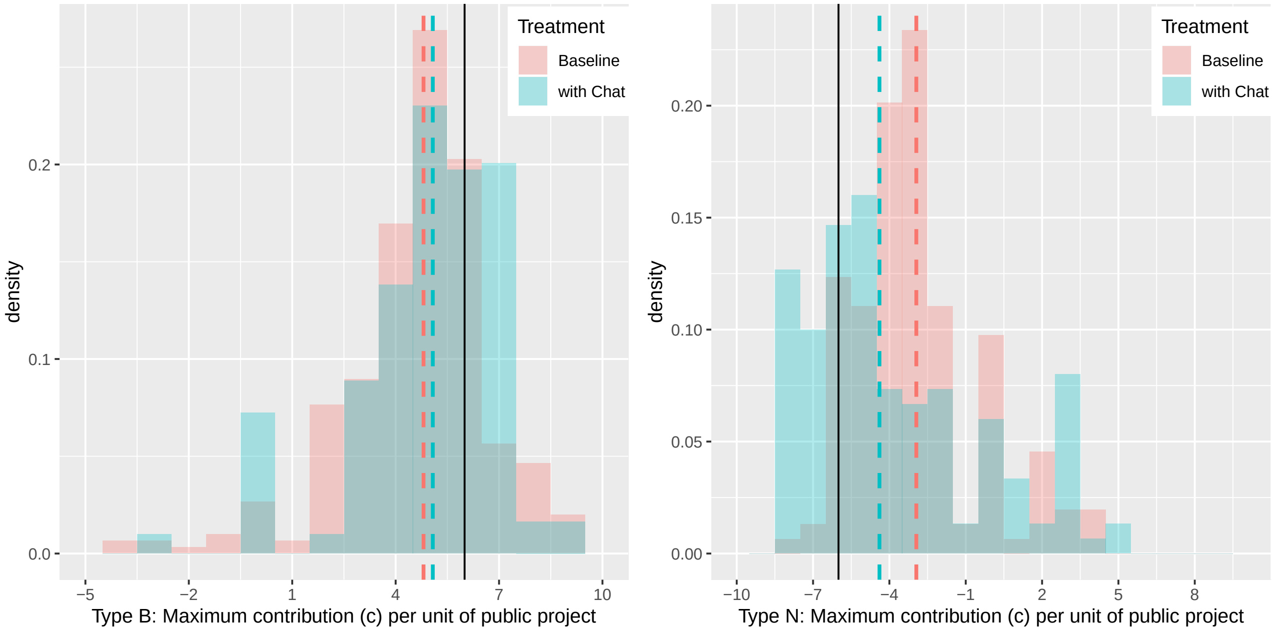
[3] We will use the symbol "±" throughout the rest of the paper for displaying standard deviations.

Figure 1: Proposed contributions (c_i) per unit of public project by treatment (within panels) and player Type (between panels).



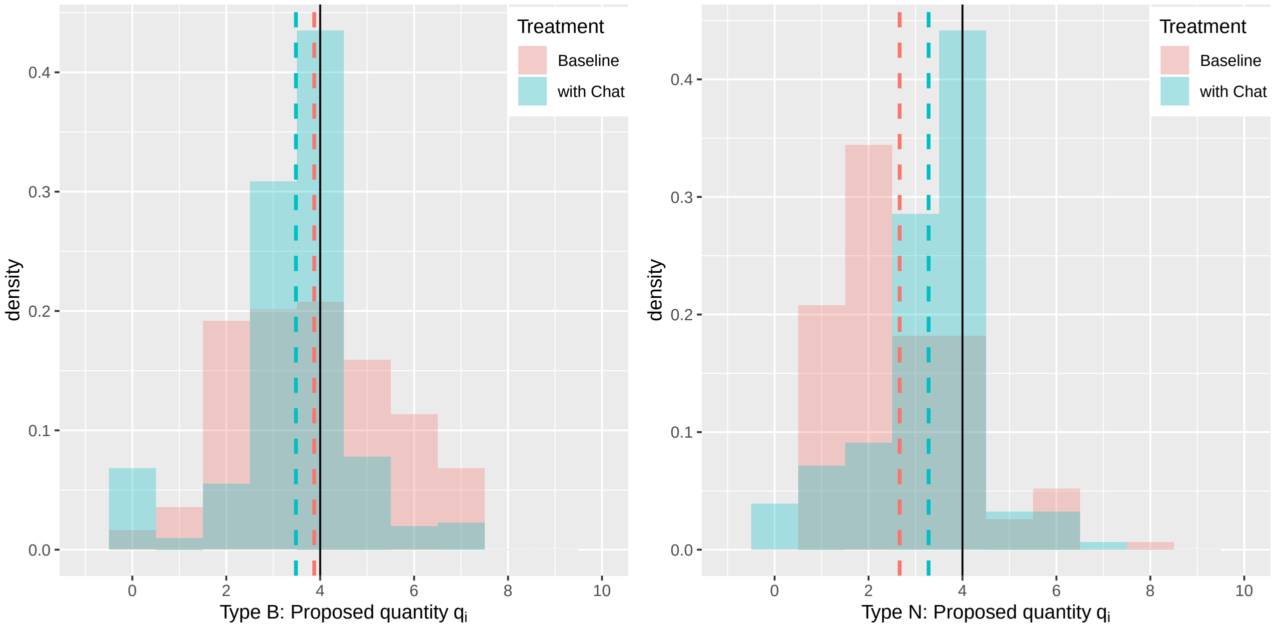
Note: The left panel corresponds to Type B players. The right panel corresponds to Type H players. Negative contributions correspond to compensation requests. We omitted the 27 intended contributions (2%) with $c_i < -10$ or $c_i > 10$.

ment. Note also that compensation requests above the Lindahl predictions ($c_i^H = -6$) occurred with a considerable high frequency (27%).

We proceed now with the analysis of proposed quantities. Table 3 reveals that Type B players request greater quantities of public project (3.69 ±1.59) than Type H players (2.92 ±1.39). Communication has opposite effects between player types: q_B decreases from 3.94 to 3.45 units (-0.48), whereas q_H increases from 2.63 to 3.21 units (+0.58) in the *Chat* treatment with respect to the baseline. Figure 2 reveals that the probability that Type B players requested the optimal value $q^* = 4$ increased more than twice with communication. This is explained by the large drop in the probability of a request q_B exceeding the optimal quantity, from 36% in the baseline to 12% in the *Chat* treatment. The probability that Type H players request $q^* = 4$ also increases more than twice with communication. In this case, smaller requests $q_N \in \{1, 2\}$ shift from 53% in the baseline to 17% in the *Chat* treatment.

Note also that vetoing the project is very unlikely in the baseline. With communication, the decision seems to arise more often from Type B players, not from Type H players. We will explore

Figure 2: Proposed quantities (q_i) by treatment (within panels) and player Type (between panels).



Note: The left panel corresponds to Type B players. The right panel corresponds to Type H players.

this in detail later.

We present now a regression analysis using a random effects model for two outcomes y_{igr}: proposed contributions c_{igr} and proposed quantities q_{igr} of each participant i, in group g, interacting in round r. Standard errors were clustered at the participant level and at the group level in separate regressions. We included round fixed effects in all models, as well as group fixed effects in the even-numbered models. We excluded the three practice rounds (1 to 3) from the analysis. The model is given by:

$$y_{igr} = \beta_0 + \beta_1 Chat_g + \beta_2 Type\,B_{ig} + \beta_3 Chat_g \times Type\,B_{ig} + \delta_r + \delta_g + \epsilon_{igr} \tag{4}$$

The variable $Chat_g$ indicates the treatment assignment (*Chat* or baseline condition), and $Type\,B_i$ indicates whether individual i was playing as Type B or Type H. Group and round fixed effects are captured in δ_g and δ_r, respectively.

Table 4 reports the estimated coefficients. We focus first on model (1). In the baseline, Type H players request on average 3.15 tokens, and Type B players propose an average contribution of (7.75 - 3.15) = 4.6 tokens. Communication increases the average requests of Type H players by 1.45 tokens, and the proposed contributions of Type B players by 1.72 tokens. Model (2) adds

Table 4: Random effects regression for proposed contributions and quantities

VARIABLES	Proposed Contributions		Proposed Quantities	
	(1)	(2)	(3)	(4)
Chat	-1.448**	-2.288$^{\circ\circ\circ}$	0.617*	0.719$^{\circ\circ}$
	(0.718)	(2.389)	(0.322)	(0.906)
	[0.723]	[0.656]	[0.324]	[0.286]
Type B	7.750***	7.750***	1.211***	1.211***
	(0.514)	(0.513)	(0.319)	(0.307)
	[0.616]	[0.630]	[0.374]	[0.383]
Chat x Type B	1.718^{*+}	1.718^{*+}	-1.006**	-1.006^{**+}
	(0.811)	(0.751)	(0.409)	(0.346)
	[0.961]	[0.984]	[0.419]	[0.429]
Constant	-3.152***	-3.186$^{\circ\circ\circ}$	2.848***	2.998***
	(0.484)	(2.202)	(0.276)	(0.878)
	[0.522]	[0.548]	[0.306]	[0.325]
Round Fixed Effects	✓	✓	✓	✓
Group Fixed Effects	✗	✓	✗	✓
Observations	924	924	924	924
Number of ID	132	132	132	132

Standard errors clustered at the participant level in parentheses and at the group level in brackets. Statistically significant when clustering at the participant and group level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Statistically significant when clustering at the participant but not at the group level: $^{+++}$ $p < 0.01$, $^{++}$ $p < 0.05$, $^{+}$ $p < 0.1$. Statistically significant when clustering at the group but not at the participant level: $^{\circ\circ\circ}$ $p < 0.01$, $^{\circ\circ}$ $p < 0.05$, $^{\circ}$ $p < 0.1$. Practice rounds (1 to 3) are excluded from the analysis.

group fixed effects. The the effect of communication on the compensations requested by Type H players increases in this specification. Since this effect is statistically significant when the standard errors are clustered at the group level, but not at the participant level, we interpret that the role of communication is highly group dependent, and not all Type H players benefit from it.

We now focus on model (3) to explore the requested quantities q_i. In the baseline Type H players proposed on average 2.8 project units, and Type B players proposed 1.2 additional project units. As we previously mention, communication increased the quantities proposed by Type H players (+0.62 units) and decreased the quantities proposed by Type B players (-1.00 unit). Adding group fixed effects, in model (4), have negligible effects on the estimated coefficients. The effect is only significant when the standard errors are clustered at the group level.

Summing up, communication increases Type B's intended contributions and Type H's requested compensations, providing support for **H1**. Nonetheless, the effects of communication

Table 5: Outcomes of the vEW Mechanism: provision, taxes, earnings, and comparisons to the Lindahl outcome: $q^* = 4$, $T^*_B = 24$, $T^*_H = -24$, and $\pi^*(q^*, T^*_i) = 46$. The reported quantities and taxes are conditional on a positive provision of the project $(q > 0)$. Practice rounds (1 to 3) are excluded.

	Baseline	Chat	Diff.	Obs.
Probability that project is provided	65.6%	68.2%	2.6%	308
Project Units	2.16	3.23	1.07	206
Provision relative to Lindahl (q/q^*)	54.0%	80.8%	26.8%	
Type B Tax	9.77	16.72	6.94	412
Type B Tax relative to Lindahl (T_B/T^*_B)	40.7%	69.7%	29.0%	
Type H Tax (Subsidy)	-6.59	-14.07	-7.47	204
Type H Tax (Subsidy) relative to Lindahl (T_H/T^*_H)	27.5%	58.6%	31.1%	
Earnings Type B	45.3	46.8	1.7	412
Type B Surplus $(\pi_B - e)/(\pi^* - e)$	94.4%	105.0%	10.6%	
Earnings Type H	35.6	38.9	3.3	204
Type H Surplus $(\pi_H - e)/(\pi^* - e)$	35.0%	55.6%	20.6%	

appear to be heterogeneous among groups. We also find that communication increased the project quantity requested by Type H players, as we predicted in **H2**. However, we did not predict that communication would trigger the opposite response among Type B players. We hypothesize that Type B players reduce the requested project quantity aiming to match the Type H player request, in order to simplify the computations of the required compensation.

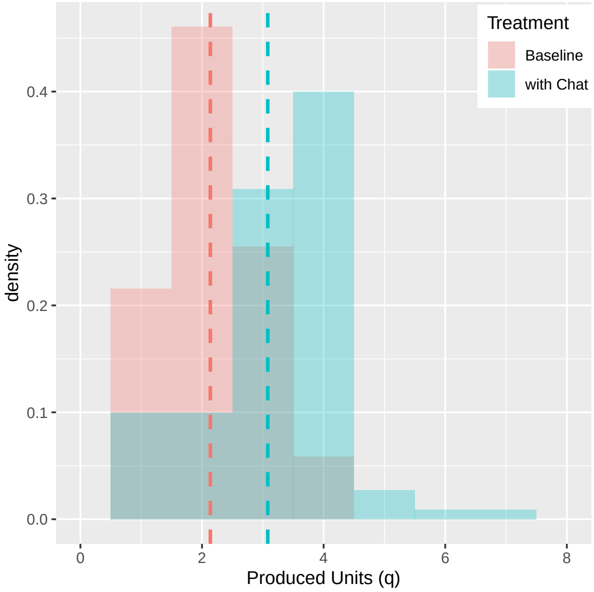
In the following section we explore whether the observed submissions $\zeta_i = (q_i, c_i)$ lead to more efficient outcomes, in the extensive (i.e., probability of project provision) and intensive (i.e., provided quantity) margins.

4.2 Outcomes of the mechanism

Table 5 reports four outcomes of interest from the mechanism. We start with the two group outcomes, whether the public project was provided and how many units were provided; and then we proceed with the two individual outcomes, the tax amount paid (or subsidy received) by player type, and the earnings by player type. We also report the relative provided quantity q/q^* and paid taxes T_i/T^*_i with respect to the Lindahl outcome. Similarly, we report the surplus generated with respect to the no provision scenario, in which $\pi_i(0,0) = e$.

The probability of project provision in the baseline is 65.6%, and communication increases this probability by 2.6 percentage points. This difference, is not statistically significant ($p-$value of a Chi-squared test is 0.628). The remaining outcomes displayed in the table are reported conditional

Figure 3: Produced units of public project (by treatment).



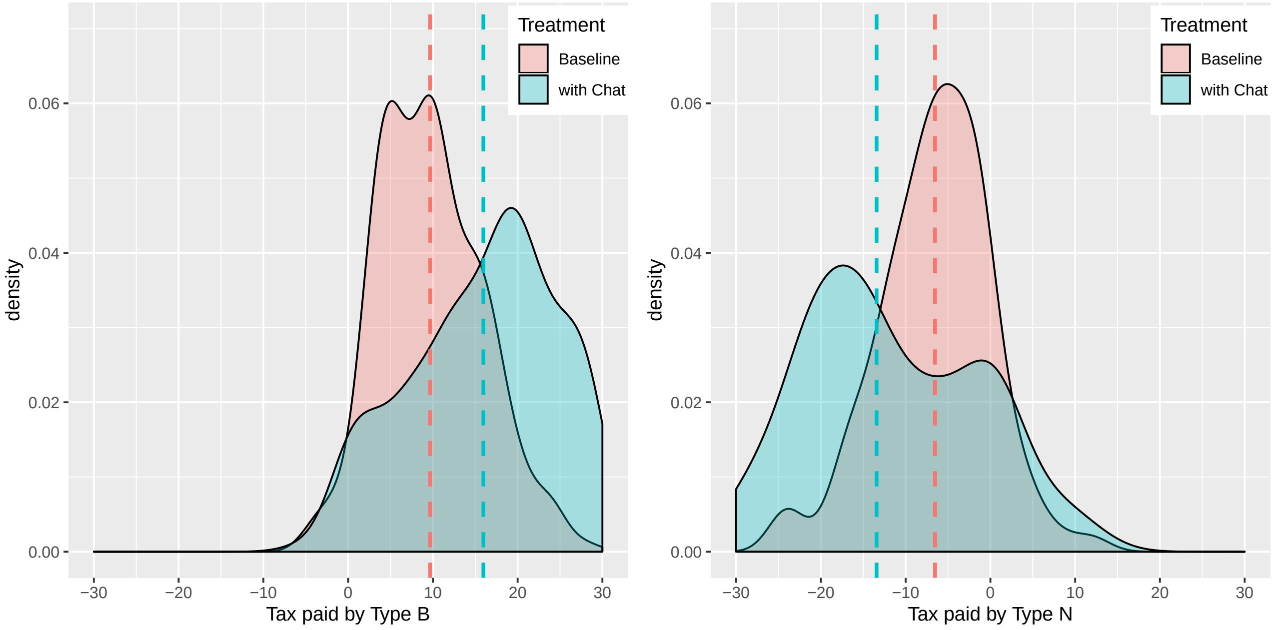
on having a positive provision $(q > 0)$.

The provided quantity increases by 1.07 units when players are allowed to chat. Relative to the efficient provision level $q^* = 4$, the additional quantity represents an increase of 27 percentage points. Figure 3 reveals that the modal provision is $q = 2$ (occurring 46.5% of the times) in the baseline, whereas in the *Chat* treatment the modal provision is $q^* = 4$ (occurring 41.9% of the times). Without communication, this optimal provision occurs in 5.9% of the outcomes.

We shift now to the individual outcomes of the mechanism. Table 5 reveals that, in the baseline, Type B players paid a tax of 9.8 tokens (4.5/unit), equivalent to 41% of the Lindahl tax; whereas Type H players receive a compensation of 6.6 tokens (3.1/unit), equivalent to 28% of the Lindahl tax. With communication, the tax paid by Type B players increases to 16.7 tokens (5.2/unit), equivalent to 70% of the Lindahl tax; whereas the compensation received by Type H players increased to 14.1 tokens (4.4/unit), 59% of the Lindahl tax. The distance to the optimal taxation levels from the Lindahl allocation becomes evident in the attained surplus, by player type. Paradoxically, the average earnings of Type B players are very close the Lindahl predictions, whereas the average cearnings of Type H players are much farther from this benchmark. This result makes evident that the redistributive potential of this mechanism is not fully exploited by the Type H Player.

Figure 4 displays the distribution of taxes per treatment and player type. The comparison within each panel confirms that communication increased the absolute value of the tax. Note that

Figure 4: Distribution of taxes by treatment (within panels) and player type (between panels).



communication creates a bimodal pattern in the distribution of taxes for the Type H player (see right panel). This result suggests that in some successful agreements (i.e., $q > 0$), the Type H player accepted agreements in which she was neither contributing nor receiving a compensation.

We can separate the increase in taxes observed in the *Chat* treatment into two components. First, the provision costs increased in 1.07ϕ given the corresponding increase in the provided quantity. Second, the remaining additional taxes paid by Type B players cover the larger compensation requested by the Type H players for allowing a larger project quantity q. Figure 5 reports the tax paid per unit, for the produced quantities $q \in \{1, 2, 3, 4\}$.[4] This metric allows us to focus on the compensation component. On the left panel we observe that, in the baseline, for $q \in \{1, 2, 3\}$ the average tax per unit paid by Type B players is virtually identical. By contrast, in the *Chat* treatment we observe a positive correlation between q and T_B. The expected opposite pattern is observed on the right panel for the average compensations received by Type H players. We observe a negative correlation between q and T_N.

Note also that the median T_N for $q = 2$ is zero. This result reflects the bimodal pattern previously observed in the distribution of T_N. Now it is clear that it occurs precisely when the Type H player receives no harm or benefit from the project (recall from Table 2 that $v_H(2) = 0$).

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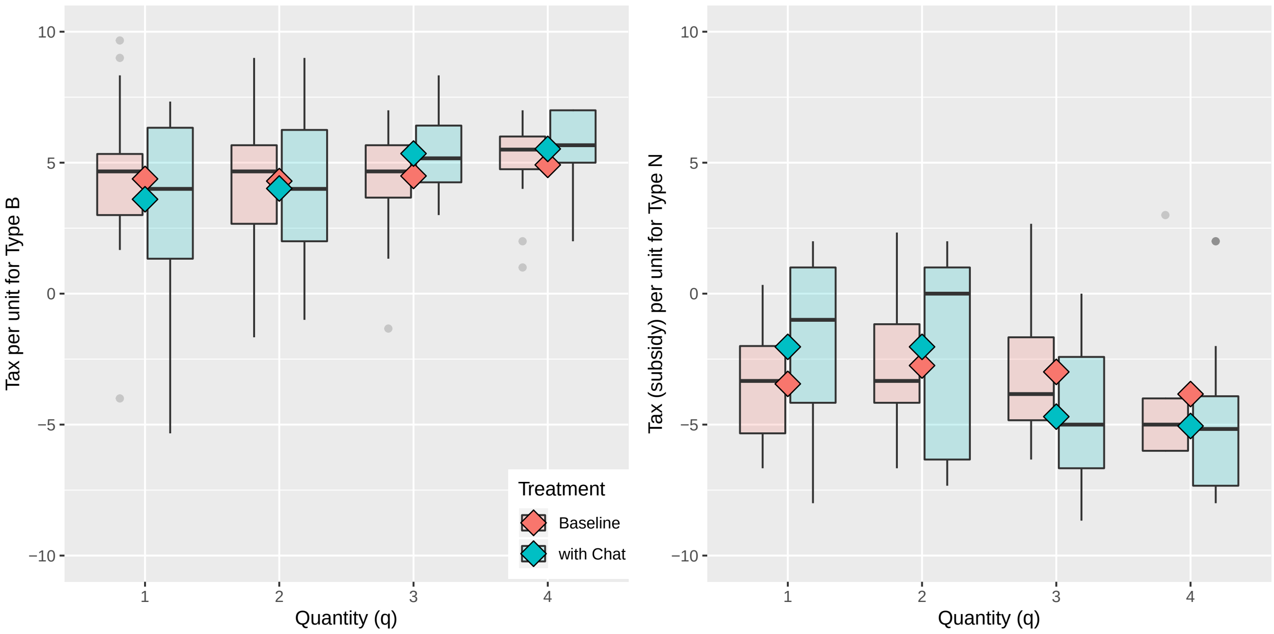
[4] They account for 98% of all outcomes involving $q > 0$.

Figure 5: Tax per unit of public project by treatment (within panels) and player type (between panels).



We conducted a regression analysis taking as outcomes the variables listed in Table 5. The model is similar to the specification displayed in Eq. 4, except that for the group outcomes we do not include group fixed effects. Table 6 reports the regression results. We confirm that communication does not increase the probability of a positive provision of the project, but it increases the provided quantity q by 1.05 units (or 55%). We do not find evidence supporting **H3**, but we validate that communication has an effect in the intensive margin, as stated in **H4**.

We now turn our attention on individual outcomes. Model (3) shows that communication increases the total tax paid by Type B players by 14.9 tokens, whereas the total compensation received by Type H players increases by 5.9 tokens (about 83% with respect to the baseline). Although these effects are large and significant, the lack of a statistically significant effect for communication in Model (4) suggests that most of the additional tax covers the additional project cost per unit ϕ, not larger compensations. Finally, Model (5) reveals that communication increases the average earnings from Type H players by 5.7 tokens, without significantly reducing the earnings from Type B subjects.

Recall that our parameterization granted equal payoffs under the Lindahl allocation and when the project is not provided. This makes even more puzzling that in the observed non-equilibrium outcomes, most of the surplus is kept by Type B players. A potential explanation is that Type

Table 6: Random effects regression for outcomes of the vEW mechanism

VARIABLES	Project Provision (1)	Quantity (2)	Total tax (3)	Tax per unit (4)	Earnings (5)
Chat	0.0260	1.045***	-5.935**	-1.180	5.653**
	(0.0613)	(0.273)	(2.821)	(0.800)	(2.379)
Type A			16.18***	7.775***	9.172***
			(2.207)	(0.736)	(1.898)
Chat × Type A			14.92***	1.770	-2.392
			(4.252)	(1.200)	(3.569)
Constant	0.692***	1.906***	-7.134***	-3.183***	35.55***
	(0.0740)	(0.162)	(1.490)	(0.490)	(1.344)
Observations	308	206	618	618	618
Groups (or subjects) in cluster	44	44	132	132	132

Clustered standard errors in parentheses. For group outcomes, in Models 1 and 2, errors are clustered at the group level. For individual outcomes, in Models 3 to 5, errors are clustered at the subjects level and group fixed effects are included. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Practice rounds (1 to 3) are excluded from the analyses.

B players use $q = 2$ as reference point because $v_B(2) = 24$ and $v_N(2) = 0$. If they successfully convince Type H player to accept this reference point they can deter the use of veto power. In Section 4.3 we analyze in detail the reasons for failed provisions, and in Section 4.4 we explore the chat logs to obtain more insights on how players interacted with the mechanism.

4.3 Failed provisions

In this Section we explore in detail what occurred in the one third of interactions in which the project was not provided. Let us start by describing the rare use of veto power. In the baseline, only 9.4% (5/53) of the failed provisions correspond to vetoing quantities. In the *Chat* treatment, this figure increases to 38.8% (19/49). Surprisingly, the use of veto was more widespread among Type B than among Type H players. In the baseline all five reports correspond to Type B players. With communication, Type B players exerted veto power 6.8% of the times (21 of 308 requests) and Type H players exerted veto power 3.9% of the times (6 of 154 requests). Neither of these differences is statistically significant.[5]

We now explore insufficient contributions, which correspond to 91% of all failed provisions in the baseline, and to 61% of all failed provisions in the *Chat* treatment. Figure 6 displays the

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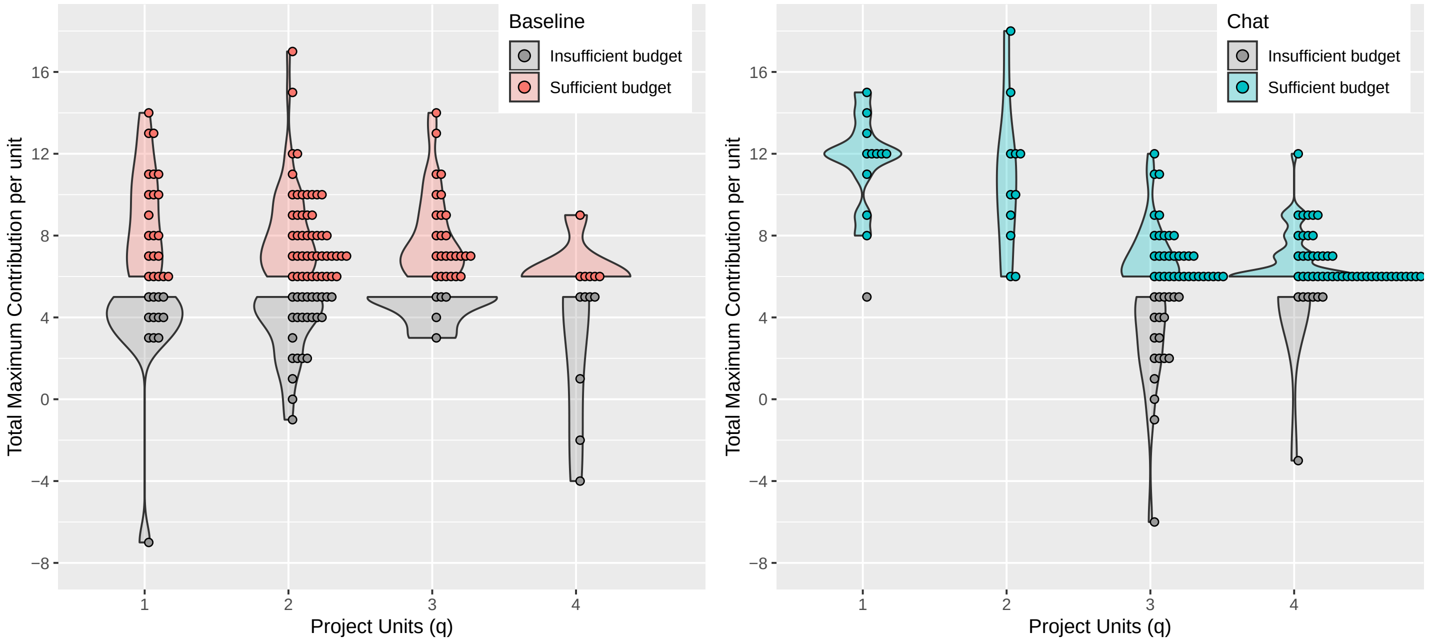
[5] The comparison between player types in the baseline using a Chi-squared test yields a $p-$value 0.112, and the comparison between player types in the *Chat* treatment yields a $p-$value 0.207).

Figure 6: Total contributions from the three group members. Colored dots (red and blue in the baseline and chat treatments, respectively) represent sufficient contributions (*i.e.*, $\sum c_i \geq 6$), and gray dots represent insufficient contributions.



Note: Total contributions displayed for $q \in \{1, 2, 3, 4\}$, which represent 98% of provisions.

distribution of successful (in color) and failed (in gray) total contributions per group. The thicker the gray distribution plots in the vicinity of $\sum_i c_i = 6$, the more evident the coordination failure. A comparison between panels reveals that, as one would expect, these coordination failures were more prevalent in the baseline. Note also that for $q = 3$, where the sum of contributions is the lowest in the *Chat* treatment, the dispersion of insufficient total contributions is the largest. This pattern suggests that the insufficient funding was not the result of coordination failures, but rather more profound disagreements regarding compensations and contributions. On the other hand, the colored distributions reveal that, when the project was provided, contributions typically exceeded the required 6 tokens, specially for $q = 1$ and $q = 2$. By contrast, for $q = 4$ the majority of total contributions were exactly $\sum_i c_i = 6$.

4.4 Analysis of chat logs

In this Section we study the content of chat logs to gain further insights on how players interact with the mechanism. We started by coding individual chat entries according to the procedure described in Appendix B.1, sorting messages into twenty-five non mutually exclusive categories defined as " message types".[6] We aggregated this information at the group×round level using an indicator variable taking the value of one if, for a given round, at least one message matched the corresponding category. Table A.1 reports the percentage of occurrence of the twenty-five message types, and its correlation with the probability of $q > 0$ in that round. We describe below the most relevant patterns.

First, veto threats from City C are uncommon, occurring only in 2% of the interactions. By contrast, it was 1.9 times more likely that City C made a request (39%), compared to the likelihood that City A/B asked City C for his approval of a given proposal (20.1%). We also highlight that in 10.4% of group interactions, City A/B explicitly talks about "compensating" City C.

Second, proposals made to City A or B, or both, occurred in 40.9% of the interactions; whereas this figure for City C is 24%. However, since two players are Type B (Cities A and B), and only one player is of Type H (City C), in relative terms were more frequent the proposals made to the host player. These proposals lead to non-binding agreements 21% of the times.

Third, game history is also frequent in chat interactions. It includes asking about the past round actions or outcomes (18%), revealing private information from the past round's payoff (20%), proposals to follow the same actions from a past round (20%), and complaining about a past outcome (16%). By contrast, players rarely reveal past choices (3%).

Fourth, requests with respect to past actions were also rare. The most frequent message of this type is to try a completely different strategy and "see what happens" (8.4%). This is followed by requests to increase the contributions (6.5%) or increase the quantities (4.5%). Only in 0.6% of the cases there was a suggestion to decrease quantities. In some rare cases there were also mentions that some specific strategies would make that everyone wins (3.2%), or that everyone loses (2.6%).

We also find that a rebate was mentioned in 3.2% of the interactions. We realized that a strategy emerging in a group was to promote a contribution per unit that was above the required 6 units, under the argument that excess contributions will be given back. Although this is a mechanic consequence of the budget balancing property, this confusion gives room to free-riding strategies that were not exploited by participants.

Only two message types were correlated with having $q > 0$: reaching a non-binding agreement ($\rho = 0.212$), and complaining about a previous round outcome ($\rho =$ -0.153). We conduct a Lasso regression as a variable selection exercise to further understand which variables, when put together, are the best predictors of $q > 0$.[7] Table 7 reports the regression coefficients for the

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[6] Since we limit the analysis to rounds 4 to 10 we dropped a category corresponding to mentions of being in a practice (or unpaid) round.

[7] A Lasso model performs a variable selection procedure by introducing a penalty in the optimization problem. This penalty in the lasso model corresponds to the absolute value of the coefficients, and is multiplied by a tuning parameter

Table 7: Estimates for the probability of provision ($q > 0$) based on chat messages. Selection of covariates based on the AIC of a LASSO model.

Message type	OLS		Random Effects	
Non-binding agreement	0.199***	(0.066)	0.202***	(0.066)
Veto threat	-0.382	(0.259)	-0.496*	(0.275)
Suggest an increase in q	-0.327*	(0.172)	-0.295*	(0.170)
Mention that a strategy "makes everyone to win"	-0.268*	(0.159)	-0.254	(0.157)
A player reveals her past payoff	-0.084*	(0.043)	-0.084*	(0.044)
Question about agreements or requests	-0.066**	(0.033)	-0.0603*	(0.034)
Constant	0.738***	(0.048)	0.733***	(0.060)
Observations	154		154	

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Practice rounds (1 to 3) are excluded from the analysis.

variables selected by the Lasso model. The coefficients (and their significance) for the estimated OLS and random effects models are similar. Non-binding agreements increase in 20 percentage points the probability of provision. The remaining covariates negatively impact the probability of provision. Note that veto threats reduce by at least 38 percentage points the probability of provision, and suggesting an increase in the project quantity reduces the probability of provision in at least 30 percentage points.

We perform an additional classification based on the content of all chat messages in a given round rather than on individual chat entries. We defined them as "chat outcomes" and divide our classifications into two groups. We report in Table A.2 the percentage of occurrence of each chat outcome, and its correlation with the probability of $q > 0$. The first group refers to the use of communication. We find that City C did not reveal her intended compensation in 11.7% of the interactions. We also find that in 14.2% of the interactions at least one of the group members did not use the chat. In the majority of these cases none of the players chatted (6.5%), followed by the cases in which only City C chatted (4.5%). The second group refers to anomalous classes of agreements. For instance, in 7% of the cases a player noted that the agreement was unfeasible given the proposed contributions. By contrast, these unfeasible agreements went unnoticed 4.5% of the times.

λ. This shrinkage penalty can reduce the weight of a coefficient up to zero, making operational the variable selection capability of the model (Tibshirani, 2011).

5 Concluding remarks

We adapted the public goods provision mechanism proposed by Van Essen and Walker to the problem of providing a noxious good in a lab experiment. The setting was framed as the provision of a waste incinerator, with a predetermined location for this facility. The provision problem dwells on defining the project size, taking into account that the host will demand a compensation to not block the provision, and that this compensation is increasing in the facility size. The mechanism is useful in this context for two reasons. First, its compensatory nature is embedded in the fact that intended contributions can be negative. That is, the host can request a compensation while the rest of users submit their contributions. Second, every member can set the maximum project size that she would allow. In other words, every user has veto power.

The mechanism operates in a simple manner. If the sum of contributions per project unit is sufficient, each user of the mechanism will contribute at most her intended contribution, and the project size will be defined by the lowest submitted quantity. The purpose of our lab experiment was to test the functioning of this mechanism in a simple setting with three players. The two players who benefit from a large noxious facility must submit sufficiently large contributions to pay the building costs and the compensation requested by the third player, who acts as the host of the facility.

We find that veto threats are seldom used by the player hosting the facility. As a consequence, most of the efficiency gains with respect to the no provision scenario are kept by the players who benefit from a larger noxious facility. The average taxes paid by these players are 41% of the Lindahl tax. This is partly because the average provision is 54% of the efficient quantity, but also because compensations to the host player are lower than predicted (28% with respect to the Lindahl prediction). We added a treatment with the possibility that group members chat during their decision. Communication has an efficiency-enhancing effect in the intensive margin, increasing the provision to 81% of the efficient quantity. However, most of the additional surplus with respect to the Lindahl allocation was kept by the players that prefer a larger facility.

The analysis of chat logs yielded two additional insights. First, non-binding agreements describing players' intended contributions increase the probability of provision by 20 percentage points. This figure could have been larger, but in 4.5% of the observed non-binding agreements the intended contributions were insufficient and players did not notice. Second, in roughly 12% of the interactions, the player harmed by the project did not reveal her intended contribution. This behavior negatively affected the probability of provision. In further implementations of this mechanism, the efficiency-enhancing role of non-binding communication should be complemented with rules that lead all players to submit their intended contributions or compensations, and to verify that these satisfy the budgetary restrictions for project implementation.

Can our results shed light on the rule-crafting of participatory FPIC processes? The mechanism's rules appear to be simple enough, the transfers become more transparent, and participants are not overusing veto power, which was a theoretical concern for implementation. More importantly, the multi-party character of this mechanism might ease the definition of "valid" actors, a current problem in FPIC processes (Rodríguez-Garavito, 2011). However, our experiment leaves as an open question what would happen if more than one party demands compensation, as could occur in the presence of multiple vulnerable communities. We are not claiming that this mechanism should replace current FPIC processes, but some of these elements can illustrate the existing tensions between beneficiaries and project hosts, and remark the compensatory nature of this problem.

From a methodological perspective, this mechanism is better suited for the study of asymmetrically valued public projects than the standard paradigms of voluntary provision of public goods (see e.g. Ledyard, 1995). Separate information on desired contributions and quantities prevents a confounding problem that the traditional voluntary contribution mechanism[8] will have in this context. A single decision on how much to contribute would not allow disentangling between egoistic (*i.e.*, free-riding) and altruistic (*i.e.*, reduce damage on those harmed by the project) motives for underprovision. In our opinion, the mechanism is simple enough to overcome the cognitive burden of submitting bi-dimensional requests (i.e., a desired quantity and a contribution per unit) in a strategic setting.

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[8] See Ledyard (1995) and Chaudhuri (2011) for survey studies.

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A Appendix: Experimental Materials

A.1 Experimental Protocol: Translated Version

Instructions

The purpose of this activity is to understand how people make economic decisions that can benefit some and harm others. We will study this problem with a hypothetical case. Pay attention because you will have to make decisions that will affect your earnings.

Construction of a waste incinerator

The National Government has suggested to Cities A, B and C to build a waste incinerator that will benefit the three cities. The only place where the incinerator can be built is in City C. Cities A and B have millions of inhabitants, so they benefit more if the incinerator to be built is larger. The incinerator has more burning towers the larger it is. City C is much smaller, so an incinerator with few burning towers is enough. The incinerator generates environmental costs that only affect City C, where the incinerator must be built. The more burning towers the incinerator has, the higher the environmental costs.

Benefits from the waste incinerator

You will make decisions for City {A,B,C}. The budget of each of the cities is 30 tokens. The maximum number of burning towers that can be built is 10. Each burning tower costs 6 tokens. An incinerator with more burning towers favors Cities A and B, but not City C. Given the population of each city and the environmental costs, the benefits are different for Cities A and B over the City C. The following table summarizes the benefits for each city:

[See Table 2]

When the values in the table are **positive**, the number of burning towers generates benefits to that City. When the values in the table are **negative**, the number of burning towers generates costs to that City.

Decision-making

You will make two decisions for {A,B,C}:

1. The maximum burning towers that you would accept to be built.

2. How many tokens are you willing to contribute for each burn tower that is built.

Your contribution can be **positive**, or it can be **negative**. A **positive contribution** is helping to **pay** the burning tower. A **negative contribution** is equivalent to asking **a compensation** for allowing the construction of the burning tower. Each burn tower costs 6 tokens, plus the sum of negative contributions (or compensations). For burning towers to be built, the sum of the contributions for each tower must be at least 6 tokens.

How is determined the number of burning towers?

Each city announces the maximum number of towers that it would accept to be built. The lowest number of towers announced by any of the cities (the minimum) will be built. Once the number of towers is defined, it should be verified if the contributions are sufficient:

- If the sum of contributions per tower is **less than** 6 tokens, the incinerator is not built.
- If the sum of the contributions per tower is **exactly** 6 tokens, each city pays the number of tokens it proposed as a contribution.
- If the sum of the contributions per tower is **greater than** 6 tokens, each city pays a smaller number of tokens than it proposed as a contribution.
  - Each surplus token is divided equally between all cities, and this amount is refunded to each city.
  - The refund is subtracted from the maximum contribution the player in charge of the city was willing to make.

Later we will see some examples and some questions to verify that you understood the rules of the game. The most important aspect of this rule is that you will never pay more than you proposed to contribute for each tower, and that the maximum number of towers that will be built will not exceed the number of towers that you are willing to accept.

The rule of how many towers are built, and how much each city contributes, can be summarized as follows:

"I will agree to any number of burning towers that is not greater than Q units (see table), as long as my contribution does not exceed P for each unit."

Communication between cities [Only in Chat treament]

During the time available to make your decisions you can communicate with the participants who represent the other cities. You can talk about proposals in terms of quantities (**Q**), and contributions (**P** positive) or compensation (**P** negative). When making a proposal, keep in mind that the amount **Q** multiplied by your proposed contribution **P** **cannot exceed** your initial number of tokens (30 tokens).

Earnings in each round

Your earnings will be equal to:

+ Endowed tokens
- (Contribution per burning tower) x (Burning towers)
+ Benefits from burning towers (see table)

Payments

You will play for a total of 10 rounds. In each round you will have a maximum of 2 minutes to make your decision. The city assigned to you, as well as the participants representing the other two cities, will be the same during the 10 rounds. Once all rounds are completed, a table will summarize the results of all rounds.

The first 3 rounds will be practice rounds. One of the remaining 7 rounds will be randomly selected to pay the three participants in the group: the representative of City A, City B, and City C. The payment will correspond to the number of tokens won, in thousands of pesos (rounded to the nearest multiple).

Negative payoffs

Pay close attention to the instructions of the game. There is a possibility of leaving with a null payment in case you do not understand the costs and benefits of the number of burning towers. If your earnings are negative in the round selected for payment, you will leave with a null payment. This has very little chance of happening, but it is important that you bear this in mind.

Please click to continue.

A.2 Experimental Protocol: Original (Spanish) Version

Instrucciones Generales

El propósito de esta actividad es entender cómo las personas toman decisiones económicas que pueden beneficiar a unos y perjudicar a otros. Vamos a estudiar este problema con un caso hipotético. Preste atención porque usted tendrá que tomar decisiones que afectarán sus ganancias por participar.

Construcción de un incinerador de basuras

El Gobierno Nacional ha sugerido a las Ciudades A, B y C construir un incinerador de basuras que beneficiará a las tres ciudades. El único lugar en que se puede construir el incinerador es en la Ciudad C. Las Ciudades A y B tienen millones de habitantes, por lo que se benefician más si el incinerador que se va a construir es más grande. El incinerador tiene más torres de quemado entre más grande sea. La Ciudad C es mucho más pequeña, por lo que un incinerador con pocas torres de quemado le basta. El incinerador genera costos ambientales que sólo afectan a la Ciudad C, donde el incinerador debe ser construido. Entre más torres de quemado tenga el incinerador, mayores son los costos ambientales.

Beneficios del incinerador de basuras

Usted tomará decisiones por la Ciudad {A,B,C}. El presupuesto de cada una de las ciudades es de 30 fichas. Se pueden construir hasta 10 torres de quemado. Cada torre de quemado cuesta 6 fichas. Un incinerador con más torres de quemado, favorece a las Ciudades A y B, pero no a la Ciudad C. Teniendo en cuenta la población de cada ciudad y los costos ambientales, los beneficios son diferentes para las Ciudades A y B respecto a la Ciudad C. La siguiente tabla resume los beneficios para cada ciudad:

[See Table 2]

Cuando los valores de la tabla son **positivos**, el número de torres de quemado generan beneficios a esa Ciudad. Cuando los valores de la tabla son **negativos**, el número de torres de quemado generan costos a esa Ciudad.

Toma de decisiones

Usted tomará dos decisiones por la Ciudad {A,B,C}:

1. El máximo de torres de quemado que aceptaría que se construyan.
2. Cuántas fichas está dispuesto a contribuir por cada torre de quemado que se construya.

Su contribución puede ser **positiva** o puede ser **negativa**. Una **contribución positiva** está ayudando a pagar la torre de quemado. Una **contribución negativa** equivale a pedir una **compensación** por permitir la construcción de la torre de quemado. Cada torre de quemado cuesta 6 fichas, más la suma de las contribuciones negativas (o compensaciones por pagar). Para que se construyan torres de quemado, la suma de las contribuciones por cada torre debe ser de al menos 6 fichas.

Cómo se determina el número de torres de quemado?

Cada ciudad anuncia el máximo número de torres que aceptaría que se construyan. Se construirá el número de torres **más bajo** anunciado por cualquiera de las ciudades (el mínimo). Una vez se define el número de torres, se debe verificar si las contribuciones son suficientes:

- Si la suma de las contribuciones por torre es **menor a** 6 fichas, no se construye el incinerador.
- Si la suma de las contribuciones por torre es **exactamente** 6 fichas, cada ciudad paga el número de fichas que propuso como contribución.
- Si la suma de las contribuciones por torre es **mayor a** 6 fichas, cada ciudad paga un número de fichas menor a lo que propuso como contribución.
    - Cada ficha adicional se divide por partes iguales entre todas las ciudades y se le devuelve a cada ciudad.
    - La devolución se resta de la contribución máxima que estaba dispuesto a hacer el jugador encargado de la ciudad.

Más adelante veremos unos ejemplos y unas preguntas para verificar que usted entendió las reglas de juego. Lo más importante es que sepa que nunca va a pagar más de lo que propuso contribuir por cada torre, y que máximo se va a construir el número de torres que usted está dispuesto a aceptar.

La regla de cuántas torres se construyen, y cuánto contribuye cada ciudad, puede resumirse así:

"Acepto cualquier número de torres de quemado que no sea mayor a Q (ver tabla), siempre y cuando mi contribución no sea mayor a P por cada unidad."

Comunicación entre las ciudades [Only in Chat treatment]

Durante el tiempo disponible para tomar sus decisiones podrá comunicarse con los participantes que representan a las otras ciudades. Usted puede hablar de propuestas en términos de cantidades (**Q**), y contribuciones (**P** positivo) o compensaciones (**P** negativo). Cuando haga una propuesta, tenga en cuenta que la cantidad **Q** multiplicada por su contribución propuesta **P**, **no** puede exceder su número de fichas inicial (30 fichas).

Ganancias de cada ronda

Sus ganancias serán iguales a:
+ Fichas iniciales
- (Contribución por torre de quemado) x (Torres de quemado)
+ Beneficios por torres de quemado (ver tabla)

Pagos por participar

Usted jugará por un total de 10 rondas. En cada ronda tendrá un máximo de 2 minutos para tomar su decisión. La ciudad que le fue asignada, así como los participantes que representan a las otras dos ciudades, serán los mismos durante las 10 rondas. Cuando complete todas las rondas aparecerá una tabla con los resultados de todas las rondas.

De las 10 rondas, las primeras 3 serán de práctica. De las 7 rondas restantes, una será seleccionada al azar para pagarle a los tres participantes en su grupo: el representante de la Ciudad A, de la Ciudad B, y de la Ciudad C. **El pago será el número de fichas ganadas, en miles de pesos (redondeados al múltiplo más cercano).**

Pagos negativos

Preste mucha atención a las instrucciones del juego, pues de no entender los costos y beneficios de la torre de quemado, existe la posibilidad de irse sin ganancias. Si en la ronda seleccionada para determinar su pago sus ganancias son negativas, usted se irá con un pago de cero. Esto tiene muy poca posibilidad de ocurrir, pero es importante que lo tenga en cuenta.

Por favor haga click para continuar.

A.3 Validation Questions

In order to continue you must answer the following questions correctly. If your response is wrong, you will get an error message within a box, including an explanation of how to compute the correct answer. You will be shown only the hint for the first question in which you have an incorrect answer. That is, if questions 5 and 8 are wrong, the hint for question 5 will appear. Once you correct the response to question 5, a hint will appear for question 8. You will find at the bottom of the page a table with the summary of the game instructions.

First scenario

City A supports the construction of up to 3 burning towers and is willing to contribute a maximum of 6 tokens per burning tower. City B supports the construction of up to 2 burning towers and is willing to contribute a maximum of 3 tokens per burning tower. City C supports the construction of 0 burning towers, and is willing to contribute a maximum of 0 tokens per burning tower.

Q1. How many burning towers will be built?

Response to Q1: Zero (0) towers.
Burning towers are not built. Although City A supports the construction of up to 3 towers, and City B supports the construction of up to 2 towers, City C does not support the construction of burning towers. The minimum number of towers proposed is then zero.

Q2. How much will City B have to pay for each burning tower built?

Response to Q2: Zero (0) tokens.
City B proposed to build 2 burning towers, and it was willing to contribute up to 3 tokens for each tower. As no burning tower was built, none of the players should contribute any of their proposed tokens.

Second scenario

City A supports the construction of up to 3 burning towers and is willing to contribute a maximum of 6 tokens per burning tower. City B supports the construction of up to 2 burning towers and is willing to contribute a maximum of 3 tokens per burning tower. City C supports the construction of up to 2 burning towers, and is willing to contribute a maximum of -3 tokens (i.e., receive at least 3 tokens) per burning tower.

Q3. How many burning towers will be built?

Response to Q3: Two (2) towers.

Two conditions must be validated. First, determine what is the minimum number of towers among all proposals. City A supports the construction of up to 3 towers, and Cities B and C support the construction of up to 2 towers. The minimum between the three cities is 2 towers. Second, determine if the contributions add up to at least 6 tokens per tower. The sum of contributions from Cities A, B and C is 6 + 3-3 = 6 tokens. This amount per burning tower covers the costs of construction and compensation, and the 2 towers can be built.

Q4. How much will City A have to pay for each burning tower built?

Response to Q4: Six (6) tokens.
City A was willing to contribute a maximum of 6 tokens per tower. Since the sum of the contributions was exactly 6 tokens (see answer to Q3), a city with a positive proposed contribution pays, for each tower built, the maximum amount it was willing to contribute.

Q5. How much will City C receive as a transfer for each burning tower built?

Response to Q5: Three (3) tokens.
City C submitted a contribution of -3 tokens per tower built. That is, it requires compensation of at least 3 tokens for allowing up to 2 burning towers to be built. Since the sum of the contributions was exactly 6 tokens (see answer to Q3), a city with negative contributions receives exactly the minimum amount requested as compensation for each tower built.

Third scenario

City A supports the construction of up to 4 burning towers and is willing to contribute a maximum of 5 tokens per burning tower. City B supports the construction of up to 5 burning towers and is willing to contribute a maximum of 4 tokens per burning tower. City C supports the construction of up to 3 burning towers, and is willing to contribute a maximum of -5 tokens (i.e., receive at least 5 tokens) per burning tower.

Q6. How many burning towers will be built?

Response to Q6: Zero (0) towers.
Two conditions must be validated. First, determine what is the minimum number of towers among all proposals. City A supports the construction of up to 4 towers, City B supports the construction of up to 5 towers, and City C supports the construction of up to 3 towers. The minimum between the three cities is 3 towers. Second, determine if the contributions add up to at least 6 tokens per tower. The sum of contributions from Cities A, B and C is 5 + 4 -5 = 4 tokens. This amount per burning tower does not cover the costs of construction and compensation, the second condition is not met, and the burning towers are not built.

Fourth scenario

City A supports the construction of up to 3 burning towers and is willing to contribute a maximum of 9 tokens per burning tower. City B supports the construction of up to 4 burning towers and is willing to contribute a maximum of 6 tokens per burning tower. City C supports the construction of up to 3 burning towers, and is willing to contribute a maximum of -6 tokens (i.e., receive at least 6 tokens) per burning tower.

Q7. How many burning towers will be built?

Response to Q7: Three (3) towers.
Two conditions must be validated. First, determine what is the minimum number of towers among all proposals. Cities A and C support the construction of up to 3 towers, and City B supports the construction of up to 4 towers. The minimum between the three cities is 3 towers. Second, determine if the contributions add up to at least 6 tokens per tower. The sum of contributions from Cities A, B and C is 9 + 6-6 = 9 tokens. This amount per burning tower covers the costs of construction and compensation, and the 3 towers can be built.

Q8. How much will City B have to pay for each burning tower built?

Response to Q8: Five (5) tokens.
Since the sum of contributions between the three cities was 9+6-6=9 tokens per tower, and only 6 tokens are needed, there is a surplus of 3 tokens. This surplus is divided by three and refunded to the cities. In this case, each city receives a rebate of 1 token. To compute the contribution of each player we subtract 1 token from the proposed maximum contribution. City B was willing to contribute at most 6 tokens per tower built. With the rebate, the actual contribution of City B will be 6-1=5 tokens per tower built.

Q9. How much will City C receive as a transfer for each burning tower built?

Response to Q9: Seven (7) tokens.
Since the sum of contributions between the three cities was 9+6-6=9 tokens per tower, and only 6 tokens are needed, there is a surplus of 3 tokens. This surplus is divided by three and refunded to the cities. In this case, each city receives a rebate of 1 token. To compute the contribution of each player we subtract 1 token from the proposed maximum contribution or compensation. City C requested a minimum compensation of 6 tokens per tower built.

With the rebate, the actual compensation of City B will be -6-1=-7 tokens per tower built.

Q10. How much will be the final earnings for City A?

Response to Q10: Thirty-nine (39) tokens.

Remember that earnings are given by the initial endowed tokens (30 tokens), minus the total contribution, plus the benefits from the built burning towers. What is the total contribution? City A was willing to contribute at most 9 tokens per tower built. Since the sum of contributions between the three cities was 9+6-6=9 tokens per tower, and only 6 tokens are needed, there is a surplus of 3 tokens. This surplus is divided by three and refunded to the cities. In this case, each city receives a rebate of 1 token. To compute the contribution of each player we subtract 1 token from the proposed maximum contribution. City A was willing to contribute at most 9 tokens per tower built. With the rebate, the actual contribution of City B will be 9-1=8 tokens per tower built. Since 3 towers will be built, City A will pay a tax of 3x8=24 tokens. When 3 towers are built, City A receives as a benefit 33 additional tokens. Therefore, earnings from City A are 30-24+33 = 39 tokens.

B Appendix: Analysis of chat logs

B.1 Coding of individual messages

The chat entries from the sessions allowing communication were manually coded by two independent raters, according to their content, following the procedure described below. First, the dataset was sorted by group and round. Second, the content of each message was classified into the following non-mutually exclusive categories, listed alphabetically.

- `agreement`: After player *i* makes a proposal, players *j* and *k* agree with it. Or, after player *i* proposes a price, player *j* agrees with this price and proposes a quantity, and player *k* agrees with both. Or, after player *i* proposes a quantity, player *j* agrees with this quantity and proposes a price, and player *k* agrees with both.

- `ask_c`: Player A/B asks Player C if she agrees with a given proposal. Or, Player A/B asks Player C how much she wants as compensation.

- `budget_concern`: A player remarks that a given contribution (or set of contributions) will be insufficient. Or, a player remarks that a given combination of p*q exceeding 30 is not feasible. Or, a player makes her contribution and demands the other players to complete a contribution of 6 units.

- `compensate_c`: Player A/B explicitly says "compensate" when describing the transfer given to/requested by Player C.

- `damage_c`: Player A/B explicitly mentions the disutility received by Player C. Or, Player A/B explicitly mentions that a change in Q will affect Player C.

- `decrease_q`: A player suggests to decrease q.

- `demand_c`: Player C makes a precise compensation request. Or, Player C requests a(n imprecise) compensation.

- `increase_contribution`: Player *i* suggests to Player *j* to increase her contribution.

- `increase_q`: Player *i* suggests to increase the project quantity.

- `past_round_choice`: A player i reveals her contribution or quantity from a previous round.

- `past_round_claim`: A player complains about the outcome of the last round

- `past_round_outcome`: A player reveals the payment from a previous round. Or, a player compares her payoff from the past round with respect to a previous round.
- `past_round_play`: A player suggests to repeat the same request from a previous round.
- `past_round_question`: A player makes a question about the outcome or choices from a previous round.
- `proposal_ab`: Player A/B makes a suggestion to player B/A regarding the contribution, the quantity, or both contribution and quantity. Or, Player C makes a suggestion to players A and B regarding the contribution, the quantity, or both contribution and quantity.
- `proposal_all`: A player makes a proposal on how all players, including herself, should play (either the contribution, the quantity, or both).
- `proposal_c`: Player A/B makes a suggestion to player C regarding the contribution, the quantity, or both.
- `question`: A player poses a question about the current round. Questions include agreements and queries about another player's requests.
- `rebate`: A player mentions that excess contributions are divided among all group members.
- `testing`: A player suggests to try a given request, and see what happens with their payoffs.
- `timeout`: A player reminds the other players to choose swiftly due to the time constraint.
- `unclear_pq`: In the message is not clear whether the player is proposing a quantity or a contribution.
- `unequal_earnings`: Player A/B mentions that Player C is supposed to earn less in this game setting. Or, A player mentions that she is earning less than the others.
- `veto_threat`: Player C makes an explicit threat of requesting $q = 0$.
- `we_all_lose`: A player mentions that, given a strategy, all three players receive lower payoffs.
- `we_all_win`: A player mentions that, given a strategy, all three players receive higher payoffs. Or, A player mentions that the idea of the game is that all players receive substantial payoffs.

B.2 Coding of group outcomes based on chat information

The chat entries from each group in each round were analyzed to classify group outcomes based on the chat history from the round interaction. Group interactions in a given round were classified into the following non-mutually exclusive categories, listed alphabetically.

- `AB_did_not_chat`: Player A/B did not intervene in the chat during the round.
- `C_did_not_chat`: Player C did not intervene in the chat during the round.
- `C_doesnotreveal_P`: Player C chatted, but never revealed the intended compensation.
- `agreement_exceeds_budget`: Players agreed on a request such that $p_i \times q_i > 30$ for at least one player.
- `did_not_chat`: Players did not chat during the round.
- `only_C_chats`: Only Player C chatted during the round.
- `prices_nonmentioned`: Neither contributions or compensations were mentioned during the round.
- `realized_insufficient_budget`: A player realizes that budget will be insufficient and proposes a different agreement.
- `rebate_toincrease_P`: Players agree on increasing their contribution to increase the rebate.
- `repeat_past_round`: Players agree on repeated the requests from a previous round.

B.3 Additional Tables

Table A.1: Percentage of occurrence and pairwise correlation with $q > 0$. Practice rounds are excluded.

Message type	Short description of message type	Occurrence [Percentage]	Correlation with $q > 0$	($p-$value)
Proposals				
`proposal_AB`	A player makes a proposal to City A/B, or to both	40.9%	-0.1121	(0.166)
`proposal_C`	A player makes a proposal to City C	24.0%	-0.0727	(0.370)
`agreement`	Players reach a non-binding agreement	20.8%	**0.2124**	(0.008)
`proposal_all`	A player makes a proposal to Cities A, B and C	13.0%	0.0566	(0.486)
Interactions with Type H player (City C)				
`demand_C`	City C makes a request	39.0%	0.0026	(0.975)
`ask_C`	City A/B asks City C about a request	20.1%	-0.0743	(0.360)
`compensate_C`	City A/B says ”compensate”	10.4%	-0.0872	(0.282)
`damage_C`	City C points out her disutility from a request	6.5%	-0.1029	(0.204)
`veto_threat`	Explicit threat from City C to request $q_i = 0$	1.9%	-0.1055	(0.193)
History of the game				
`past_round_outcome`	A player reveals her payoff from a past round	20.1%	-0.109	(0.178)
`past_round_play`	A player suggests to repeat the request from a past round	20.1%	0.03	(0.712)
`past_round_question`	A player asks about an action/outcome from a past round	18.2%	-0.1117	(0.168)
`past_round_claim`	A player complains about a past outcome	16.2%	**-0.1529**	(0.058)
`past_round_choice`	A player reveals her request from a past round	3.2%	0.0465	(0.567)
Modify requests				
`testing`	Try a new strategy to see what happens	8.4%	0.0068	(0.933)
`increase_contribution`	A player suggests to increase the contribution	6.5%	-0.1029	(0.204)
`increase_q`	A player suggests to increase the quantity	4.5%	-0.1186	(0.143)
`we_all_win`	A mention that a given strategy makes a win to all	3.2%	-0.1108	(0.171)
`we_all_lose`	A mention that a given strategy makes a loss to all	2.6%	0.0239	(0.769)
`decrease_q`	A player suggests to decrease the quantity	0.6%	0.0552	(0.496)
Other message types				
`question`	Queries about agreements or player’s request	35.7%	-0.1309	(0.106)
`timeout`	A reminder to choose rapidly given the time constraint	11.7%	0.0316	(0.698)
`unequal_earnings`	A mention that City C is supposed to earn less	3.2%	-0.1108	(0.171)
`rebate`	A mention that excess contributions are rebated	3.2%	-0.0322	(0.692)
`unclear_pq`	Not clear if the message contains c_i or q_i	1.3%	-0.0448	(0.581)

Table A.2: Chat outcomes. Percentage of occurrence and their pairwise correlation with a positive provision of the project ($q > 0$). Practice rounds (1 to 3) are excluded from the analysis.

Chat outcome	Short description of chat outcome	Occurrence [Percentage]	Correlation with $q > 0$ ($p-$value)	
Use of communication				
`C_doesnotreveal_P`	City C did not reveal intended compensation	11.7%	-0.099	(0.224)
`did_not_chat`	Players did not chat	6.5%	0.010	(0.899)
`only_C_chats`	Cities A and B did not chat	4.5%	0.015	(0.852)
`C_did_not_chat`	City C did not chat	1.9%	0.096	(0.235)
`AB_did_not_chat`	City A/B did not chat	1.3%	0.078	(0.334)
`prices_nonmentioned`	Contributions not mentioned	1.3%	-0.045	(0.581)
Type of agreements				
`noted_insufficient_PQ`	A player noted the agreement is unfeasible	7.1%	**-0.189**	(0.019)
`agreement_exceeds_PQ`	Players agree on an unfeasible request	4.5%	**-0.253**	(0.002)
`repeat_past_round`	Players agree on repeating a past request	1.9%	-0.005	(0.955)
`rebate_toincrease_P`	Players agreed on increasing the rebate	1.3%	-0.045	(0.581)